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(54) **Wide angle passive infra-red intruder detector**

(57) A passive infra-red detection apparatus is described, which comprises an infra-red sensor array (16) mounted in a housing (10), and a focusing reflector system (20, 22) and focusing refractor (14) which focus infra-red radiation from different distance ranges onto the sensor array (16). The sensor array (16) comprises at least three sensing elements or groups of elements (16A, 16B, 16C) spaced apart transversely with respect to the lens axis of the focusing refractor (14). Thus in combination with a multiple reflector (20, 22) having at least three reflector surfaces and/or a multiple focusing Fresnel refractor (14), the sensor array receives several different views spaced apart transversely thereby providing a wider viewing angle than the prior art construction. Thus, the present detector is more suited to use with a closed-circuit television (CCTV) surveillance system.

FIG.1.

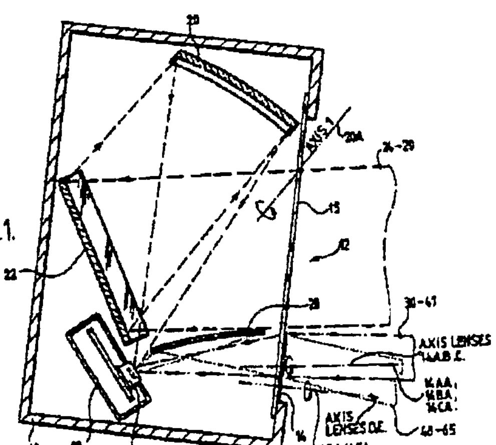
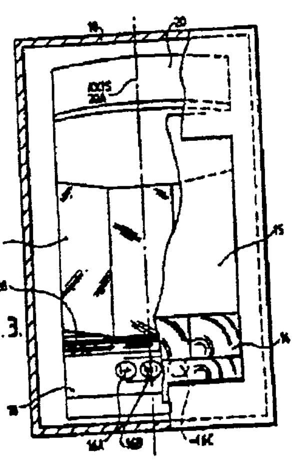


FIG.3.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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WIDE-ANGLE INFRA-RED DETECTION APPARATUS

This invention relates to infra-red detection apparatus having an infra-red pyro-electric sensor and long pass filter combined with a focusing mirror, plane mirror and Fresnel lens array.

Such apparatus is disclosed in our European Patent Publication No. 0537024A. The combination of the lens array and mirrors produces discrete spaced-apart fields of view which in a typical embodiment provide a 'curtain of coverage' in a vertical plane. Detection apparatus using this arrangement is suitable for use along the perimeter boundary of a secure area and to provide an alarm signal whenever the fields of view are traversed by an intruder. The alarm signal may be used to activate an alarm system, CCTV surveillance system, security lighting or other response system.

Field experience indicates that when the apparatus is located with CCTV cameras and used as a motion sensor to activate video recording equipment or other warning systems, it can have certain shortcomings. Firstly, the area covered by the known apparatus extends typically 100 metres with a radial spread of some 3 degrees, whereas the area covered by a typical CCTV camera lens is invariably wider, typically 20 degrees. Thus, when co-located with a CCTV camera, the existing apparatus does not provide motion sensing over the whole area covered by the camera lens. Secondly, when used in rural outdoor locations, alarm activation may be caused by warm-blooded animals such as rabbits, dogs and foxes moving into the fields of view where they impinge the ground. Whilst these activations may have little consequence when used with a CCTV system, they can cause an undesirably high false-alarm rate when the apparatus is combined with intruder alarm systems and CCTV cameras are not installed.

It is an object of the invention to provide improved infra-red apparatus.

According to this invention, infra-red detection apparatus comprises an infra-red sensor array mounted in a housing, a focusing reflector system constructed and arranged in the housing to focus infra-red radiation received from a first range of distances onto the array, and a focusing refractor constructed and arranged in the housing to focus infra-red radiation from a second range of distances onto the array, the second distance range encompassing distances shorter than the first distance range, wherein the sensor array comprises at least three sensing element or groups of sensing elements, which elements or groups are spaced apart transversely with respect to a lens axis of the focusing refractor, and wherein the focusing reflector system includes a multiple reflector having at least three reflector surfaces each oriented to direct incoming radiation to a different transverse position on the sensor array.

In a preferred embodiment of the invention the housing has a front window forming at least part of a front wall of the housing and the reflector system comprises a first mirror mounted within the housing in a rearward position with respect to the window and directed generally towards the window, and a second mirror above or below the window and the first mirror and directed generally towards the first mirror, the sensor array being respectively below or above the window and the first mirror, whereby infra-red radiation entering the housing through the window is reflected by the first mirror onto the second mirror where it is then reflected onto the sensor array. The multiple reflector may be a single multi-faceted mirror having three or more facets angled with respect to each other or it may be a group of mirrors angled with respect to each other. In the case of the focusing reflector system comprising a first, plane reflector and a second, concave reflector, it is preferably the plane reflector which is multi-faceted or consists of differently angled plane mirrors, but it is possible for the concave reflector to have a plurality of concave facets or sections each having a focusing axis angled with respect to the axes of the other facets or sections. As a result it is possible to produce a well-defined image from infra-red radiation emitted by a body at a range in excess of 25 metres, and preferably in excess of 50 metres over an area radially spaced 10°, preferably 15°, either side of a centre axis.

The sensor array of the preferred embodiment has a number of sensors which corresponds to the number of reflector surfaces of the multiple reflector, and each sensor has two sensing elements arranged side-by-side in the transverse direction, i.e. along the line of sensing elements running transversely to the refractor lens axis referred to above. The orientation of the reflector surfaces is such that the combination of the focusing reflector and the sensor array has a plurality of pairs of fields of view radiating from the front window of the housing, the number of pairs being equal to the multiple of the number of sensors and the number of reflector surfaces of the multiple reflector. Preferably, the arrangement of the reflector surfaces and the sensors is such that the individual fields of view or pairs of fields of view are in groups such that the complete viewed sector covered by the arrangement is divided into a plurality of consecutive smaller sectors each corresponding to a respective one of the groups, with the number of groups corresponding to the number of reflector surfaces. Within each group there is a number of individual fields of view or pairs of fields of view corresponding to the number of sensors receiving radiation from the respective reflector surface.

Whether each group contains individual fields of view or pairs of fields of view depends on whether the sensors each contain one or a pair of sensing elements. It will be appreciated that if each of the sensors contains more than two sensing elements, each group will be made up of sub-groups of three or more fields of view.

A similar arrangement of fields of view at closer ranges may be provided by arranging for the focusing refractor to have a plurality of lenses with differently oriented lens axes, each lens accounting for a number of pairs of fields of view corresponding to a number of dual-element sensors. The lenses are preferably Fresnel lenses formed in the same piece of infra-red-transparent material as a plain window portion for the passage of radiation received by the reflector system.

To reduce false alarms due to the number of fields of view, the sensors are connected to an electronic signal processing arrangement preferably mounted inside the housing and constructed so that an alarm condition is signalled only when at

least two sensor output signals occur at different respective sensor outputs within a predetermined time interval. The output signals may be changes in voltage level of one or more sensing elements of a sensor, or changes in the difference between the output voltage levels of two sensing elements of the sensor. Thus, an intruder moving across different fields of view will cause successive output signals in different sensors, giving rise to an alarm condition, whereas occasional, spasmodic movements due to small animals, for example, are more likely to produce output signals in only one sensor within the predetermined time interval. The interval is typically 10 seconds, but may be in the range of 3 seconds to 30 seconds.

In this way it is possible to provide coverage to match the coverage of typical CCTV lenses while substantially reducing the false alarm rate from animals which would normally result when a multiple fields of view system is used in an outdoor environment.

It has been stated above that the focusing reflector system receives radiation from a first range of distances while the focusing refractor receives radiation from a second range of distances, the second range encompassing distances which are shorter than the first range. Advantageously, the focusing refractor can be made up of lenses which produce fields of view spaced not only angularly over the viewed sector, but also spaced in a vertical plane so as to define different ranges corresponding to different declinations with respect to the horizontal. Additional, shorter, ranges may be produced by including a further reflector in the housing which is located so as to receive radiation via the lenses from a steeper angle of declination for reflection onto the sensors. This reflector may be a mirror having a reflecting surface which is curved so as to increase the aspect ratio of the fields of view provided by this reflector in comparison with the aspect ratio of the other fields of view. In other words the image of a radiating object incident on the sensor array is reduced in height in comparison with its width. This may be achieved by arranging for the reflecting surface to be concave and to have its smallest radius of curvature about a horizontal axis running transversely to the lens axis or axes. In particular, the reflecting surface may be part-cylindrical about such a horizontal axis.

The overall field of view of the preferred apparatus is in the region of 30 degrees (15 degrees either side of the central axis), extending to a maximum distance of 50 to 80 metres when the apparatus is located at about 2.3 metres above the ground, the double fields of view due to the reflector system being arranged to decline and impinge on the surface at typically 70 metres range. Consequently, an intruder crossing the area of coverage would normally be detected after travelling 5 metres or less.

The energy collected from an intruder within a field of view of a given solid angle remains substantially constant with increasing range providing he fully fills the field of view. Although the energy decreases with the square of the distance, the area of the target covered by the field of view increases with the square of the distance to compensate. Thus the signal obtained when an intruder crosses into a field of view remains substantially constant at increasing distance until he no longer fully fills the field of view, whereupon the signal diminishes with the square of the distance. It follows that it is preferable to use relatively long focal length systems for long range imaging. In the preferred embodiment of the invention fields of view beneath the main, long range rank, i.e. additional to those provided by the reflector system, are arranged to decline at greater angles in order to detect intruders moving closer to the detector and beneath the level of the main fields of view. In practice it is desirable to arrange that the lower ranking fields of view have focusing systems, i.e. the Fresnel lenses referred to above, with focal lengths shorter than the main fields of view. This is beneficial for two reasons: Firstly, a shorter focal length allows the use of smaller apertures (lenses) for the same or similar f number. Secondly, the area covered where the wider angle field of view impinges on the ground is larger than would be the case with a long focal length system, therefore small animals are less likely to fill the field of view fully.

In the preferred embodiment the main rank of nine double fields of view is supplemented by four additional ranks each angled downwardly to a different extent with the steepest rank declining some 30 degrees from the horizontal. These fields of view are produced by a system having a focal length of around half that of the

reflector system producing the main rank. In an ideal system each downward rank would have a focal length to suit the coverage required such that the steepest ranks (closest to the detector) might have a focal length some 10 percent of the main rank, but for practical reasons of manufacturing simplicity the present apparatus uses two focal lengths, typically about 100 mm for the main ranks (the reflector system) and 50 mm for the lower ranks (the focusing refractor), i.e. the focal length of one is about one half of the focal length of the other. To increase further the area of ground covered by the steepest two ranks, the preferred apparatus uses a secondary cylindrically curved reflector, as mentioned above, which modifies the aspect ratio of the fields of view to have height to width ratios of typically 4:1 compared to the 2:1 ratio of the other ranks. Thus the area of the ground covered by these steeper fields of view is elongated thereby reducing the chance of animals filling the field of view but ensuring that a normally vertical intruder still fully fills it. The reflector is curved in one plane only to cause this vertical elongation of the fields of view.

The preferred apparatus also has the following features. It has passive infra-red sensor means, a focusing reflector constructed and arranged to focus infra-red radiation received by the apparatus from a first distance range on the sensor means, and focusing refractors constructed and arranged to focus infra-red radiation received by the apparatus from a second distance range on the sensor means, the second distance ranges being shorter than the first distance range. The focusing refractors are an array of Fresnel lenses formed in a sheet of polyethylene material, the array of lenses causing radiation received from an object within the second distance ranges to converge on the sensor means, which are positioned at or near the focal plane of the array of lenses. The sensor means and the reflector are contained within a housing one wall of which is formed as a window facing the scene to be surveyed. Advantageously, the window is a polyethylene film, part of which, preferably a lower part, is formed as an array of Fresnel lenses, and another part of which is parallel-sided so as to pass infra-red radiation largely without refraction.

The focusing reflector may be a concave mirror arranged to receive radiation through the plane portion of the window from objects in the first distance range to cause such radiation to converge on the sensor means. A second, plane reflector is used as an intermediate reflector in the optical path between the window and the above-mentioned focusing refractor. For instance, if the sensors are located in a lower part of the housing at or near the effective focal plane of the Fresnel lenses, the concave reflector is best positioned in the top part of housing with its reflective surface facing downwards and away from the window, and the second reflector is best mounted generally at the same level as the plain, parallel-sided part of the window rearwardly with respect to the concave reflector oriented so that radiation from a distant object is reflected upwardly to the concave reflector which then reflects the radiation downwardly to converge on the sensor means. The sensor means are located at or near the focal plane of the concave reflector, i.e. at or near the intersection of the focal planes of the concave reflector and the Fresnel lenses. It will also be appreciated that a similarly compact arrangement may be achieved with the sensor means in an upper part of the housing and with the concave reflector in a lower part.

In practice, when the apparatus is mounted some distance above the ground, for example at a height of two metres or greater, the positioning of the sensor means and the optical components described above determines the effective ranges within which radiation sources may be detected according to the inclination of the paths of the incoming radiation with respect of the horizontal. Thus, radiation emanating from a body less than 25 metres from the apparatus will be incident upon the window at a greater angle with respect to the horizontal than radiation emanating from a body at, for example, 50 metres. Accordingly, the positioning of the concave and plane reflectors with respect to the sensor means and the parallel-sided part of the window is arranged such that radiation from objects at a distance of 50 metres or greater is directed onto the sensor means, while the position of the sensor means with respect to the lower part of the window, containing the Fresnel lenses is such that the sensor means receive radiation only from objects at a distance of 25 metres or less. The apparatus includes a second reflector in the region between the

Fresnel lens or lenses and the sensor means and alongside the radiation path therebetween in order to reflect radiation instant upon the Fresnel lens at a steeper angle of inclination (i.e. emanating from objects much nearer than 25 metres) onto the sensor means. When the sensor means are located in a lower part of the housing, it is advantageous that this second plane mirror has a downwardly facing surface and is positioned generally above the path of radiation travelling directly between the Fresnel lens and the sensor means so that the reflector can act as a shield protecting the sensor means from direct sunlight.

The complete disclosure of the above-mentioned European Patent Publication No. 0537024A is incorporated as part of the subject matter of this specification and drawings by reference.

The invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a sectional side view of apparatus in accordance with the invention;

Figure 2 is a front view of a window of the apparatus of Figure 1;

Figure 3 is a partly cut-away front elevation of the apparatus of Figures 1 and 2;

Figures 4A, 4B and 4C are respectively a front elevation, a bottom plan view, and a cross-sectional side view of a plane mirror array mounted in the apparatus of Figures 1 and 2;

Figure 5 is a diagrammatic side view illustrating the fields of view of the apparatus, shown in a vertical plane;

Figure 6 is a diagrammatic plan view showing the same fields of view as shown in Figure 5;